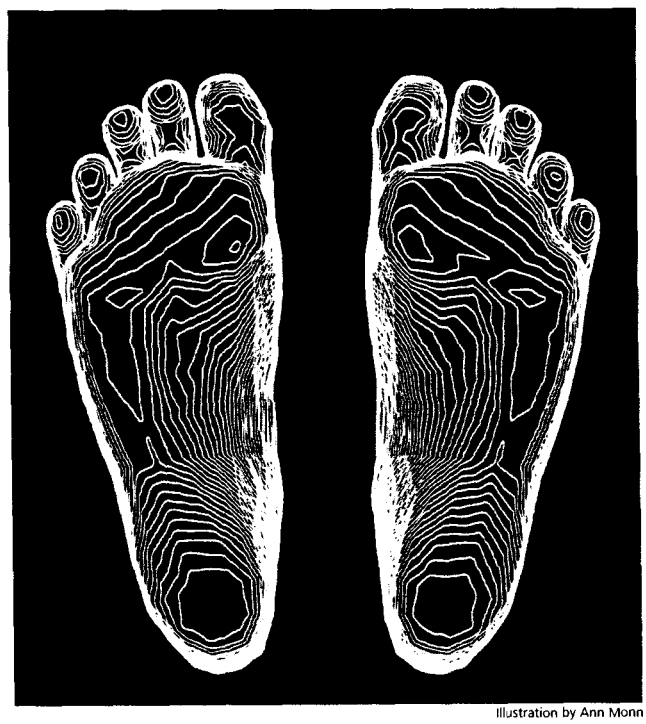

Illustration by Ann Monn

Four Ears to the Ground

By Alan Burdick

FROM TIME TO TIME, leaving the American Museum of Natural History after hours, I pass the elephants in the Akeley Hall of African Mammals. They occupy the center of the room: a cluster of them, on a wide dais, milling eternally in the state of taxidermy. Aside from them and me and a savanna of glass-eyed ungulates, the hall is empty. My footsteps produce the only sound, which seems somehow amplified by the elephants' great mass.

We share a regular, wordless dialogue, the elephants and I, but only lately have I come to understand what they have to say. **For** years now, scientists have understood that elephants communicate at a frequency typically too low for the human ear to perceive—20 Hz. Propagating through the air, these vocal calls can reach an elephant 9-10 km away. For better reception, the listening elephant spreads its earflaps forward, effectively transforming its head into a satellite dish.

As it turns out, that is only half the story. Recently a Stanford University researcher, Caitlin O'Connell-Rodwell, discovered that an elephant's

Conservation In Practice
A Publication of the Society for Conservation Biology

Editorial Office
Conservation In Practice
Department of Biology, Box 351800
University of Washington
Seattle, WA 98195-1800 USA
www.conbio.org/InPractice

printed on recycled paper with soy ink

vocal call actually generates two separate sounds: the airborne one and another that travels through the ground as a seismic wave. Moreover, the seismic version travels at least twice as far, and seismic waves generated by an elephant stomping its feet in alarm travel farther still, up to 33 km. What's most remarkable, however, is how elephants presumably perceive these signals: they listen, it seems, with their feet.

Seismic communication is widespread. Creatures from scorpions to crocodiles rely on ground vibrations to locate potential mates and to detect (and avoid becoming) prey. The male fiddler crab bangs territorial warnings into the sand with its oversized claw. A blind mole rat pounds its head against the walls of its underground tunnels, thus declaring its dominance over the other blind mole rat two tunnels over, which may or may not be listening with its own head pressed to the wall.

O'Connell-Rodwell was first inspired by the seismic songs of planthoppers, tiny insects she studied early in her career. The planthopper sings by vibrating its abdomen; this causes the underlying leaf, and ideally all nearby planthoppers, to tremble. She observed that planthoppers in the peanut gallery would lift a foot or two, presumably for better hearing: the other feet, bearing more weight, thus become more sensitive to vibration. Years later, O'Connell-Rodwell saw similar behavior among elephants at a water hole in Namibia. Minutes before a second herd of elephants arrived, members of the first group would lean forward on their toes and raise a hind **leg,** as if in anticipation. "It was the same thing the planthoppers were doing," she says.

Was it? Several elegant experiments by O'Connell-Rodwell demonstrate that elephants do indeed generate long-range seismic signals. But can other elephants hear them? Early evidence from northern California's Oakland Zoo, where an elephant named Donna is being trained to respond exclusively to seismic clues, strongly suggests that the answer is yes. "We haven't sealed the deal," says O'Connell-Rodwell, "but it looks promising."

As a communication medium, she notes, seismic waves would offer the elephant several advantages. They dissipate less quickly than airborne waves, they aren't disrupted by changes in weather or temperature, and they aren't swallowed by dense jungle foliage. Complex vocal harmonics don't translate well into seismic waves. But even the simplest long-range message—"I'm here" or "Danger!"—beats a fancy one that can't be heard at all.

Air is the faster medium: an airborne elephant call will reach a distant listener before the seismic one does. The delay between signals may confer its own advantage, however, O'Connell-Rodwell proposes. The delay increases with distance; an astute listener would soon learn to gauge distance from the delay. Combined with its airborne counterpart, a seismic signal would enable the animal to coordinate its movements with faraway colleagues, to forage more effectively, and to detect unseen danger. It is compass, yardstick, and e-mail in one—an elephantine Palm Pilot.

And the elephant's palm is the key, O'Connell-Rodwell believes. It may be that the seismic vibrations propagate from the elephant's feet to its inner ear—a process known as bone conduction. That would explain some of the odder features of elephant anatomy, including the fatty deposits in its cheeks, which may serve **to** amplify incoming vibrations. In marine mammals, similar deposits are called "acoustic fat."

But O'Connell-Rodwell thinks the elephant ear may be tuned even more

acutely to the ground. "They do have nerves connected to their toenails, and they do lean on them. It could be a direct line to their head." **A** colleague is now exploring whether the fleshy pad of an elephant's foot contains Pacinian and Meissner corpuscles, specialized nerve endings that detect faint motion and vibration. The tip of an elephant's trunk has more of these structures per square centimeter than does any other animal organ, and it is supremely touch-sensitive. (In addition to lifting a foot to improve its hearing, an elephant sometimes holds its trunk to the ground, as if it were an amplifier, says the Stanford biologist.)

All of which raises the question, Which is doing the hearing here—the elephant foot or the elephant ear? The truth is, "hearing" is a semantic distinction, a construct of human language. To us, a "sound is what happens when airborne acoustic waves vibrate tiny hairs inside our head. ***An*** "ear" is an acoustic organ that looks like ours.

Properly defined, however, sound is a series of compression waves in any medium: air, liquid, solid matter. Animals have evolved all manner of translating these mechanical waves into neural signals. **A** fish senses motion with a line of specialized receptors on both sides of its body. Walk toward a fish tank, and your footsteps startle the fish. Did it hear you or feel you? To the fish, there's no difference.

Perhaps, in our ear-0-centric view of the world, we have constrained our senses. "The animals have been paying attention to something that we haven't been noticing," O'Connell-Rodwell says. Lately she has begun exploring the possibility that other large mammals—bison, rhinoceroses, hippopotamuses, lions, giraffes—rely on seismic cues in their daily lives.

Paradoxically, the discovery that elephants and perhaps other large mammals may communicate seismically comes at a time when it is increasingly difficult for us to hear them. Just as the night sky is becoming obscured by "light pollution" from countless street-lights and other artificial sources of illumination, so the sounding board of earth has become muddled with "bioseismic noise": rumbling trucks, electric generators, jet vibrations, the hum and trundle of civilization and commerce. Does this human static disrupt elephant conversations in the wild? Does it drive them nuts in captivity? The zoo environment is stressful enough without having to hear from every pothole within a **30-km** radius. Then again, I manage to sleep through the most fearsome Manhattan traffic. "My guess is, elephants in urban environments have become desensitized to seismic signals, as people have," suggests O'Connell-Rodwell.

In the end, the primary casualty of bioseismic noise is us. The human foot happens to be a remarkably sensitive listening device. It is nearly **as** dense with pressure receptors as is the elephant's trunk. O'Connell-Rodwell suspects that once upon a quieter time, we paid closer attention to seismic signals than we do today. Vibrations from instruments such **as** the talking drum or the didgeridoo, or even from foot-stomping dances, may have spoken volumes to distant, unshod listeners. Then came telephones, automobiles, asphalt—and footwear. We hardened our soles to the world of sound.

The echo of my footsteps haunts me now. When last I strolled through the darkened Akeley Hall, it struck me that this is what it would be like to be entombed in a shoe. The silent elephants, the hushed lions, the stilled giraffes—a continent of primordial instincts urged me toward the exit: loosen, unlace, enter the world barefoot. *

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